U.S. CLIVAR Hurricane Working Group Workshop: 5-7 June 2013, Princeton, NJ

Intense precipitation events associated with landfalling tropical cyclones in a warmer climate

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and Modelers for the U.S. CLIVAR Hurricane Working Group

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(2) **INGV** - Istituto Nazionale di Geofisica e Vulcanologia (National Institute for Geophysics and Volcanology), Bologna, Italy
(3) **IIHR**-Hydroscience & Engineering, The University of Iowa, Iowa City, Iowa
(4) **GFDL** – Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey.

Istituto Nazionale di Geofisica e Vulcanologia

Centro Euro-Mediterraneo sui Cambiamenti Climatici

BACKGROUND & MOTIVATION

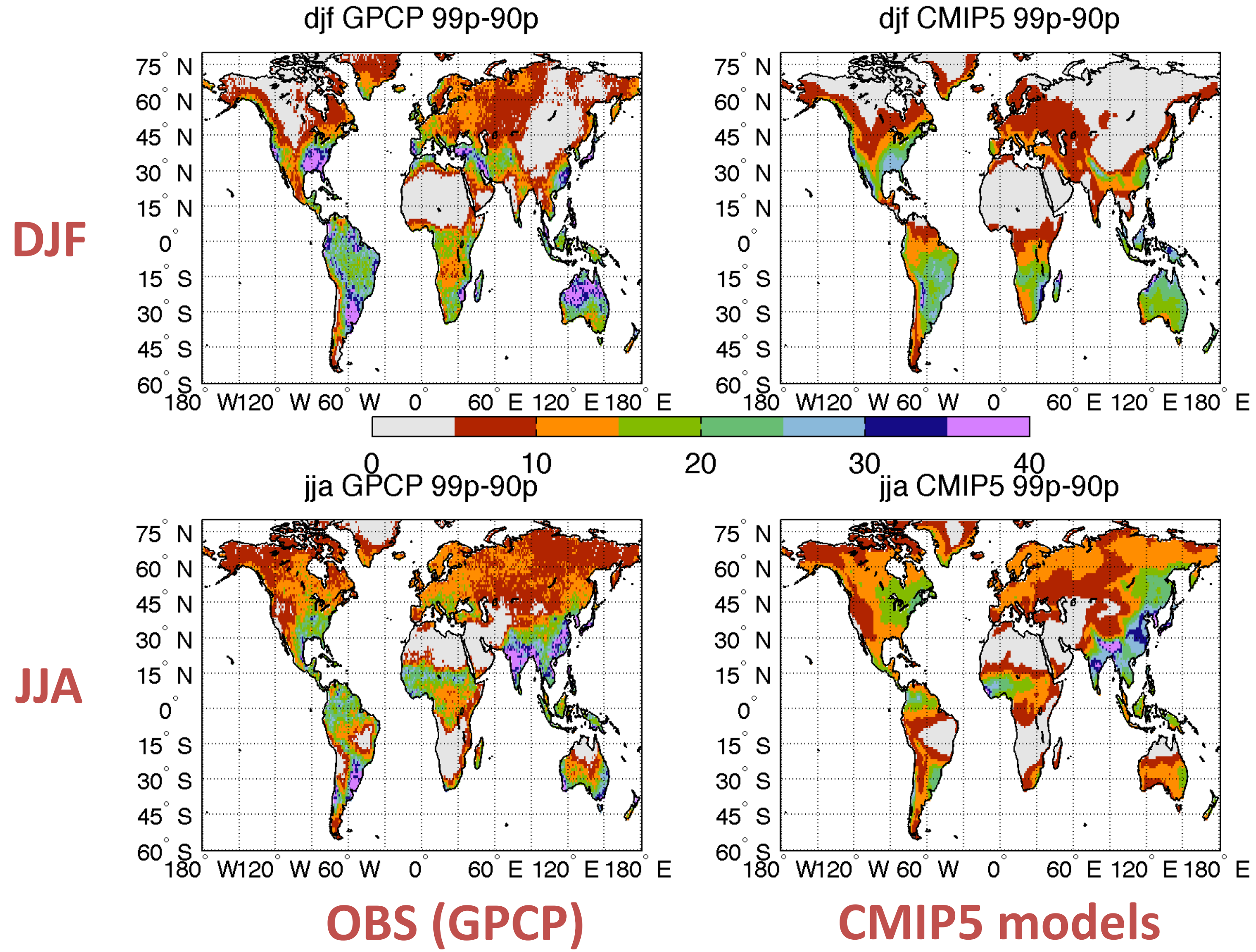
In the past a number of investigations have been done to explore the **effects of global warming on the precipitation associated to Tropical Cyclone** (e.g.,Gualdi et al. 2008, Knutson et al. 2004; Hasegawa and Emori, 2005). Despite the agreement in claiming that TC-related rainfall rates are likely to increase with greenhouse warming, the range of projection for the late twenty-first century between existing studies is very large (+3 to +37%, Knutson et al. 2010) and depending on the different used methodologies.

Rainfall is projected to increase over land, **both in terms of average and extremes** (Liu et al. 2009, Chou et al. 2009). Since there is a **large spatial variability** (Trenberth et al. 2011, Scoccimarro et al. 2013) associated to changes in projected rainfal amount , we would **verify and quantify the LANDFALLING TCs contribution region by region.**

The **availability of a set of** high resolution GCMs and **simulations following common protocols (the HWG ones)**, should strengthen the projected information.

MOTIVATION

CMIP5 (20 models) difference between 99th and 90th percentiles (99p-90p) [mm/d] in 1997-2005



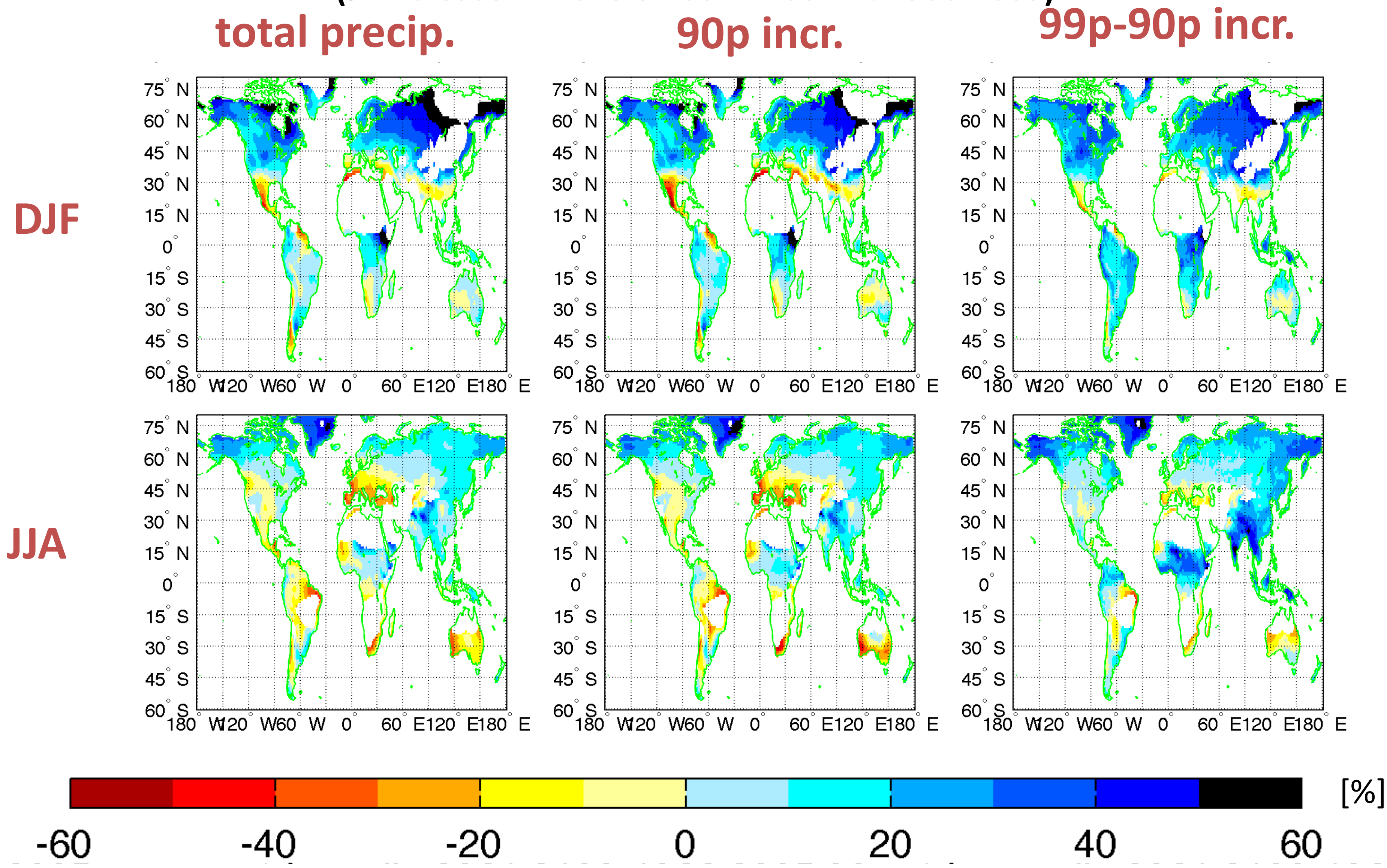
Scoccimarro, E., S. Gualdi, A. Bellucci, M. Zampieri, A. Navarra (2013):
***Heavy precipitation events in a warmer climate: results from CMIP5 models*,**
Journal of Climate, DOI: 10.1175/JCLI-D-12-00850.1

MOTIVATION

CMIP5 (20 models) total precipitation, 90p and 99p-90p

CHANGES IN A WARMER CLIMATE

(% increase in RCP8.5 2061-2100 wrt 1966-2005)



DATA and METHODS

Observed TC tracks → **National Hurricane Center** and **Joint Typhoon Warning Center**
Tropical Cyclone Best Track Data.
Period: 1980 – 1989.
Frequency: 6h.

Observed Precipitation → **Global Precipitation Climatology Project**
(GPCP; Huffman et al. 2001)
Period: 1980 – 1989.
Frequency: daily.

GCMs HWG results
(tracks and precipitation) → **CMCC model** **(Echam5 at 80 km of horiz. res. & 31 vertical levels)**
GFDL model **(HIRAM at 50 km of horiz. res. & 32 vertical levels)**

Period: - 10y of present day simulation CONTROL
- 10y of doubling CO2 exp. 2xCO2
- 10y of present SST+2K degrees exp. p2K
- 10y of doubl. CO2 ans SST+2K exp. p2k2xCO2

Frequency: 6h (tracks)
daily (precipitation).

DATA and METHODS

Informations about HWG models used

	GFDL	CMCC
	HIRAM	ECHAM5
Spatial Resolution	50 km	80 km
Vertical levels	32	31
Precipitation param.	Bretherton et. al 2004, Rotstayn 1997, Rotstayn 2000.	Tiedtke 1989, modified following Nordeng, 1994.
Reference	Zhao, M., I.M. Held, S-J. Lin, and G.A. Vecchi, 2009: Simulations of Global Hurricane Climatology, Interannual Variability, and Response to Global Warming Using a 50km Resolution GCM. J. Climate, 33, 6653-6678.	Roeckner, E., and Coauthors, 2003: The atmospheric general circulation model ECHAM5. Part I: Model description. MPI Rep. 349, 127 pp.

DATA and METHODS

TC DETECTING algorithm used

	GFDL	CMCC
DETECTING	1) Relative vorticity at 850 hPa larger than 1.6×10^{-5} s^{-1} is found within areas of 6°x6° latitude and longitude. 2) The local minimum of sea level pressure (within a distance of 2° latitude or longitude from the vorticity maximum) is defined as the center of the storm. 3) The local maximum temperature averaged between 300 and 500 hPa is defined as the center of the warm core. The distance of the warm-core center from the storm center must not exceed 2^o. The warm-core temperature must be at least 1^oK warmer than the surrounding local mean.	1) Relative vorticity at 850 hPa is larger than 1×10^{-5} s^{-1} 2) There is a relative surface pressure minimum, and the surface pressure anomaly, compared to a surrounding area with a radius of 350 km, is larger than 2 hPa 3) In a region with a radius of 350 km around the grid point considered, there is a grid point where the maximum surface wind velocity is larger than 15.5 ms^{-1}. 4) Wind velocity at 850 hPa is larger than wind velocity at 300 hPa 5) The sum of temperature anomalies at 700, 500, and 300 hPa is larger than 1^o K, where anomalies are defined as the deviation from a spatial mean com-puted over a region with a radius of 350 km.

DATA and METHODS

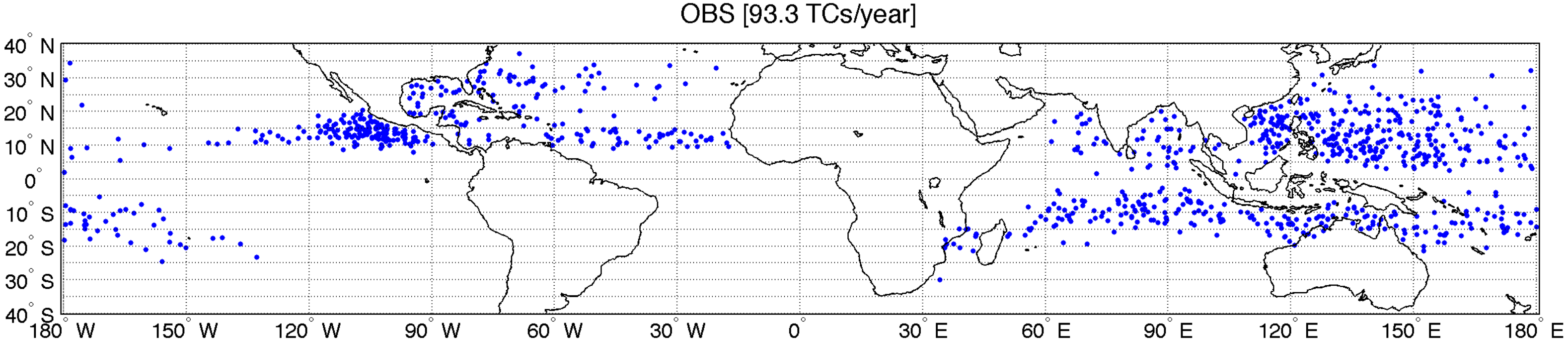
TC TRACKING algorithm used

	GFDL	CMCC
TRACKING	4) For each detected snapshot, a check is performed to see if there are storms during the following 6-h time period within a distance of 400 km. 5) If there are none, the trajectory is considered to have stopped. If there are some, the closest storm is chosen as belonging to the same trajectory as the initial storm. If there is more than one possibility, preference is given to storms that are to the west and poleward of the current location. 6) To qualify as the model storm trajectory, a trajectory must last at least 3 days, and have a maximum surface wind speed greater than 17 ms^{-1} during at least 3 days (not necessarily consecutive).	6)) For each detected snapshot, a check is performed to see if there are storms during the following 6-h time period within a distance of 300 km. 7)) If there are none, the trajectory is considered to have stopped. If there are some, the closest storm is chosen as belonging to the same trajectory as the initial storm. If there is more than one possibility, preference is given to the nearest storm. 8) To qualify as the model storm trajectory, a trajectory must last at least 1 day (corresponding to four time steps of the model output)

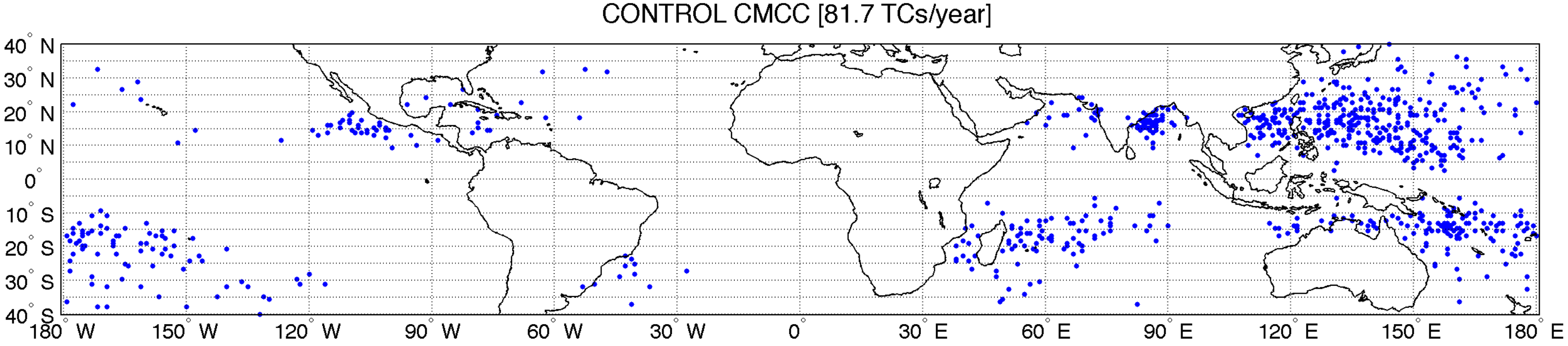
RESULTS

TC genesis location in present climate CONTROL simulation (10y)

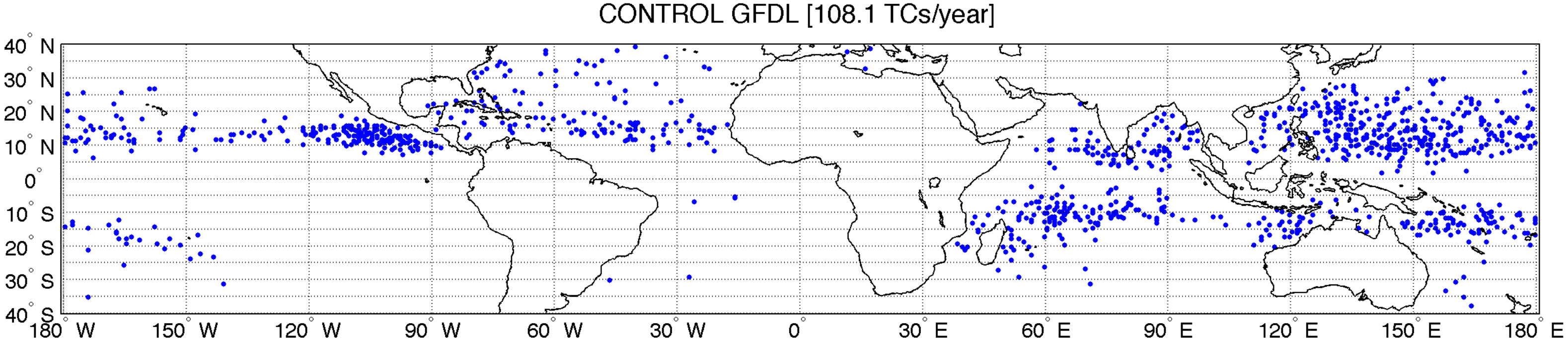
OBS
(93.3 TCs/y)



CMCC
(81.7 TCs/y)



GFDL
(108.1 TCs/y)



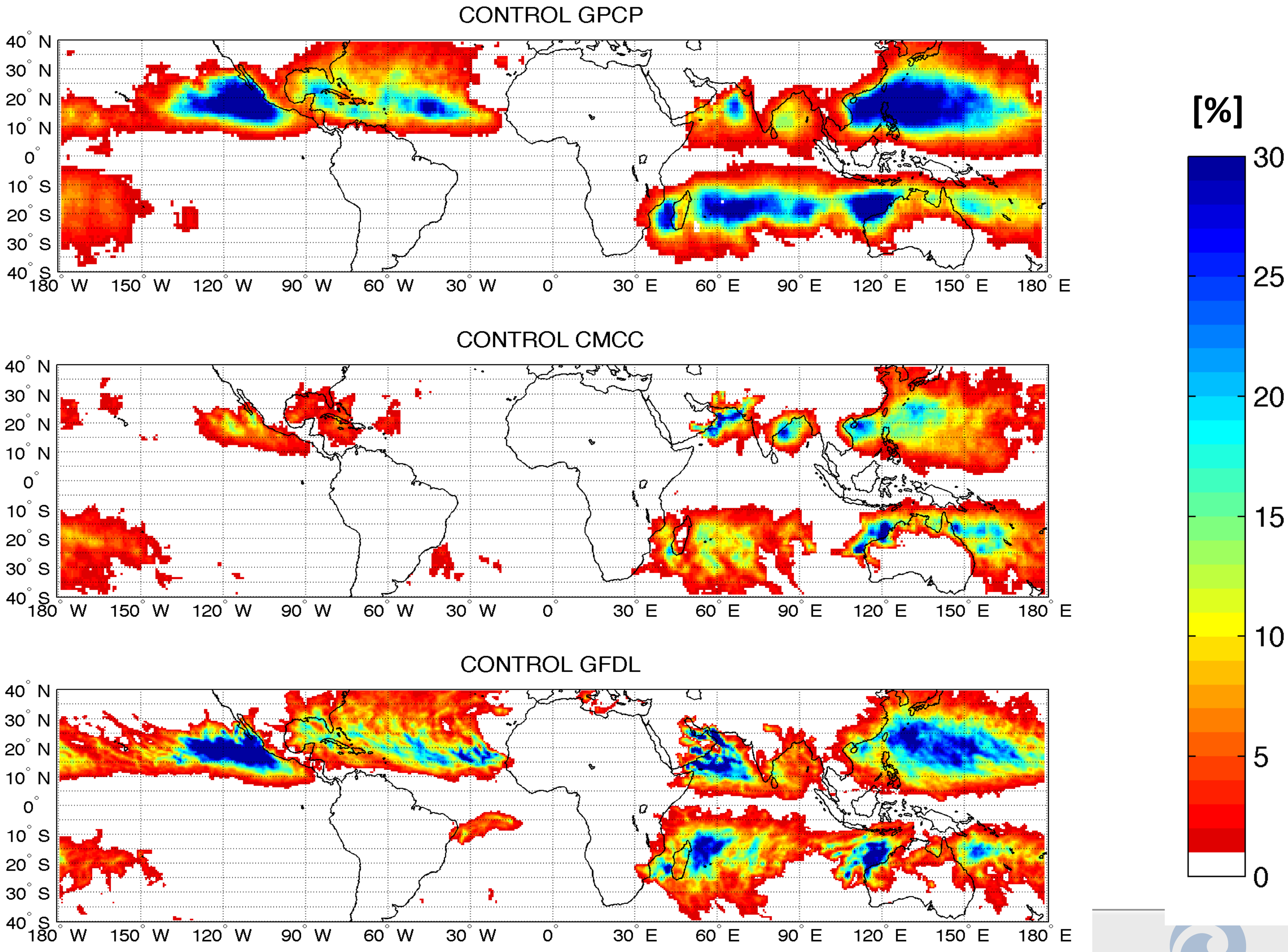
RESULTS

Fraction of precipitation associated with TCs in the CONTROL (10y) experiment [% wrt the total]

OBS (GPCP)

CMCC

GFDL



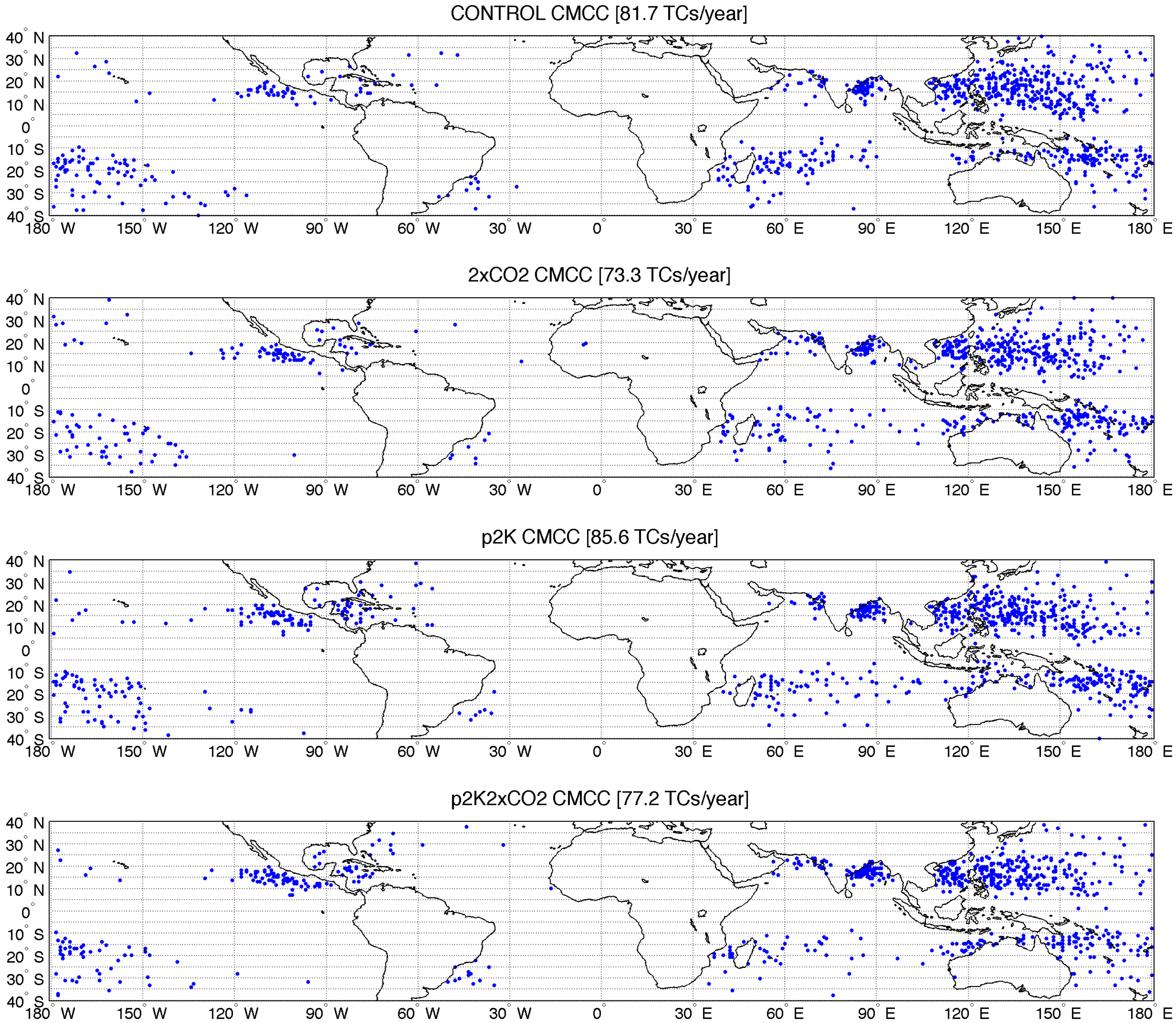
RESULTS
CMCC model TC genesis point in HWG experiments

CONTROL
(81.7 TCs/y)

2xCO2
(73.3 TCs/y)

p2K
(86.6 TCs/y)

p2K2xCO2
(77.2 TCs/y)



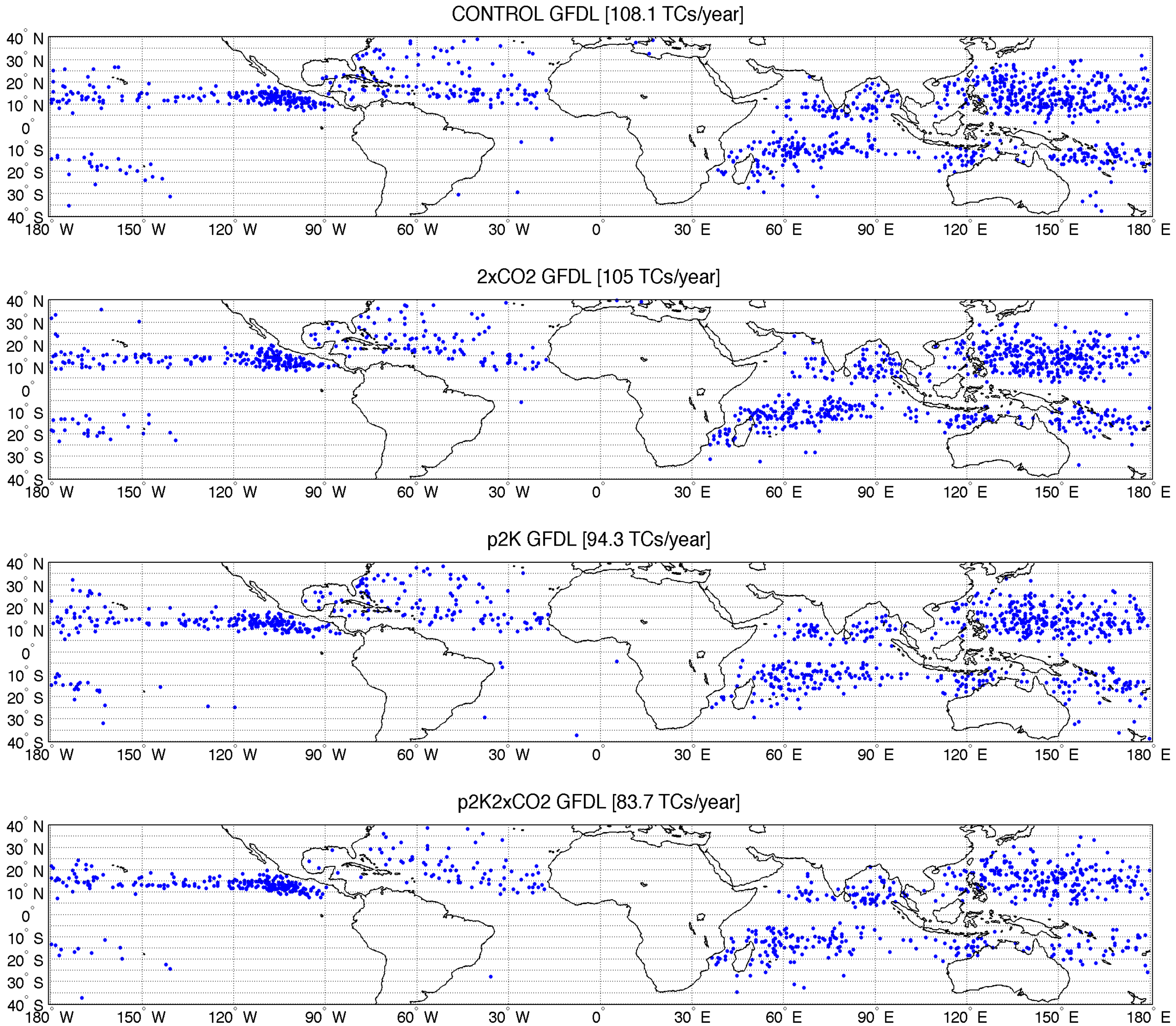
RESULTS
GFDL model TC genesis point in HWG experiments

CONTROL
(108.1 TCs/y)

2xCO2
(105 TCs/y)

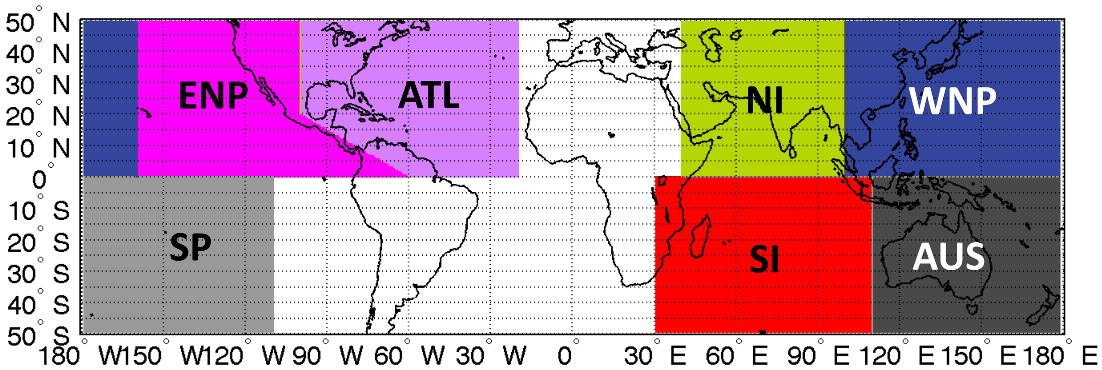
p2K
(94.3 TCs/y)

p2K2xCO2
(83.7 TCs/y)

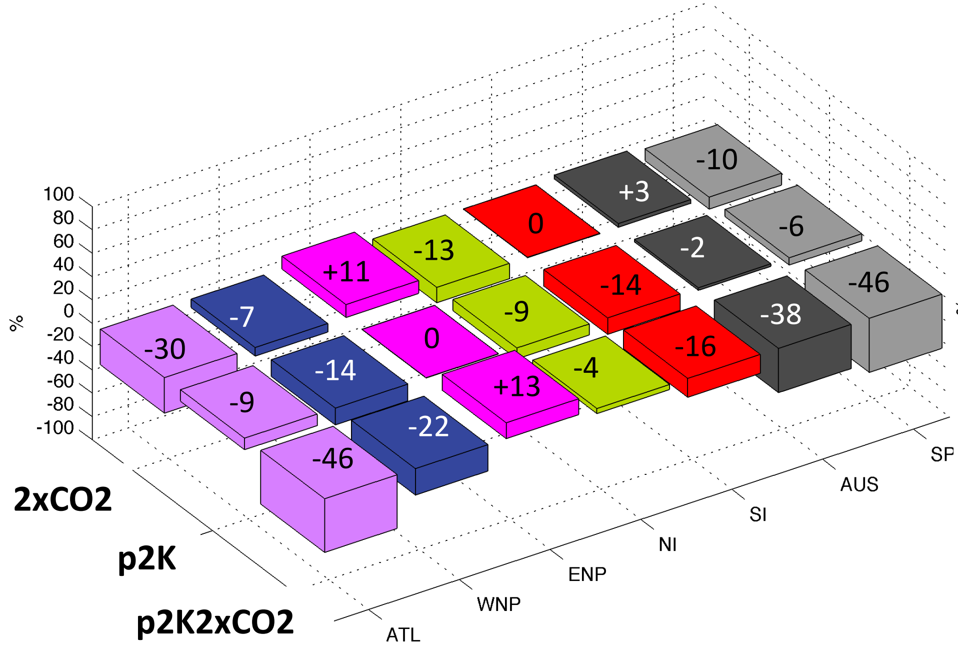


RESULTS

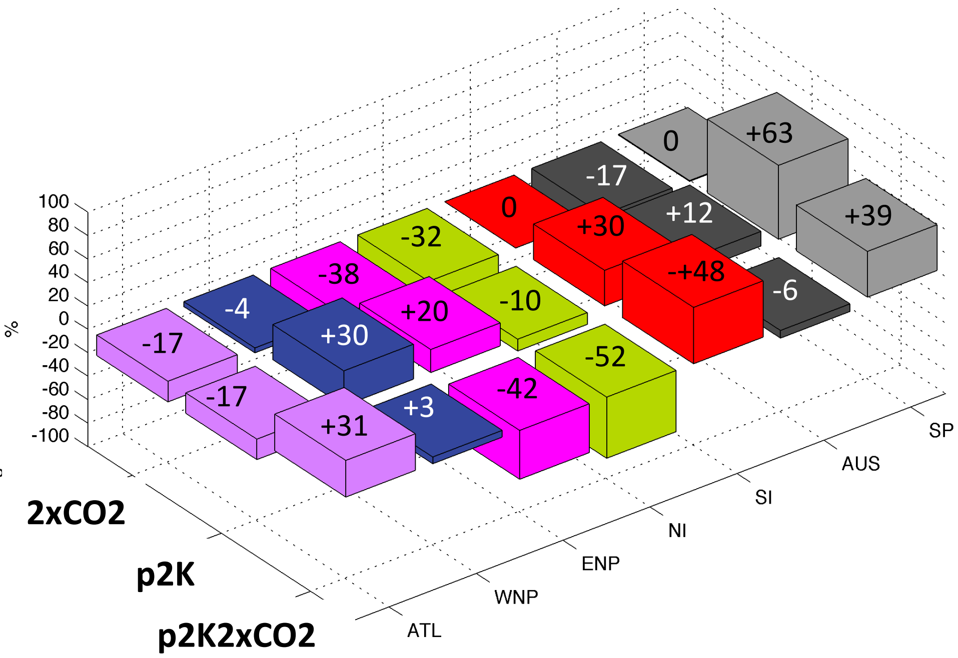
Changes in the total amout of water associated to TCs region by region in the HWG experiments



GFDL TC precipitation increase [% wrt CONTROL]

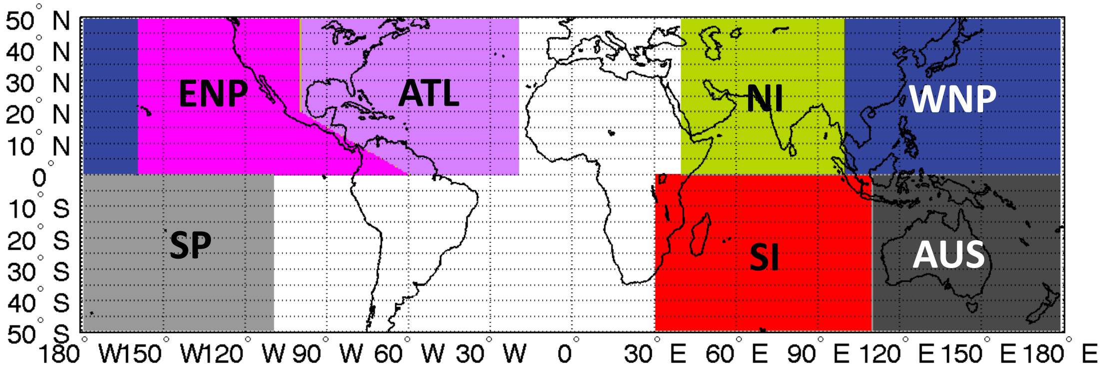


CMCC TC precipitation increase [% wrt CONTROL]

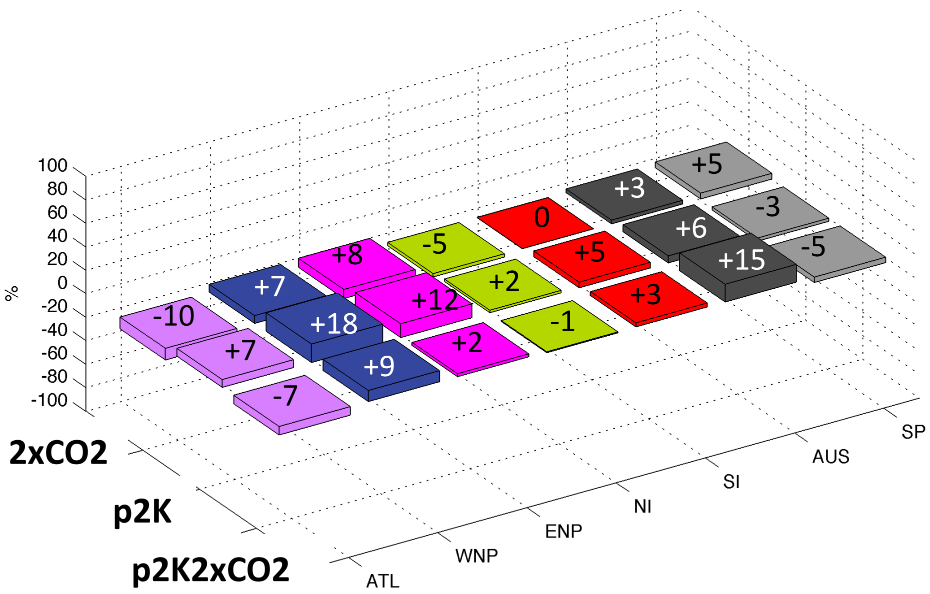


RESULTS

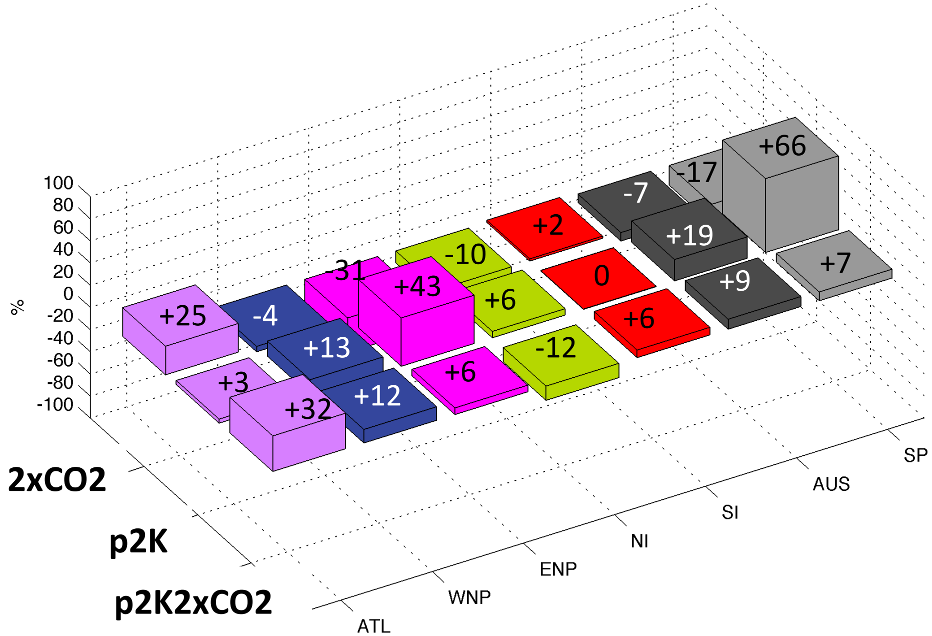
Changes in the total amout of water associated to TCs, NORMALIZED BY TCs DAYS



GFDL TCprecip/TCdays increase [% wrt CONTROL]

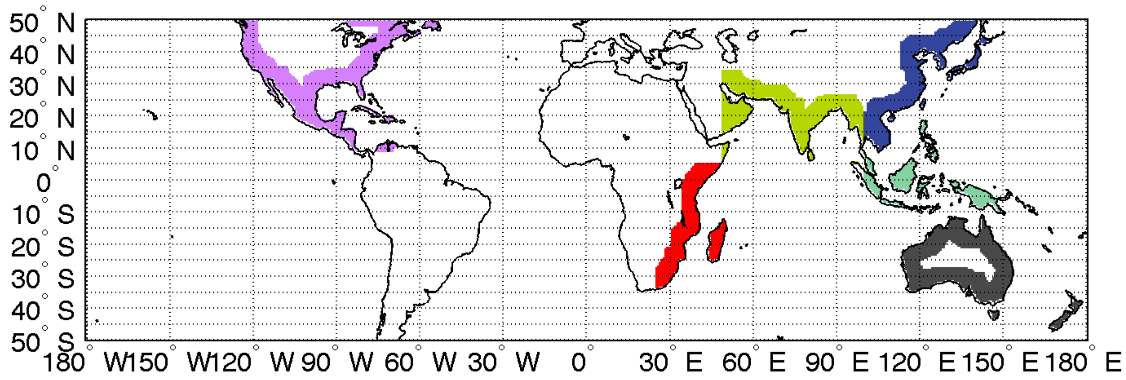


CMCC TCprecip/TCdays increase [% wrt CONTROL]

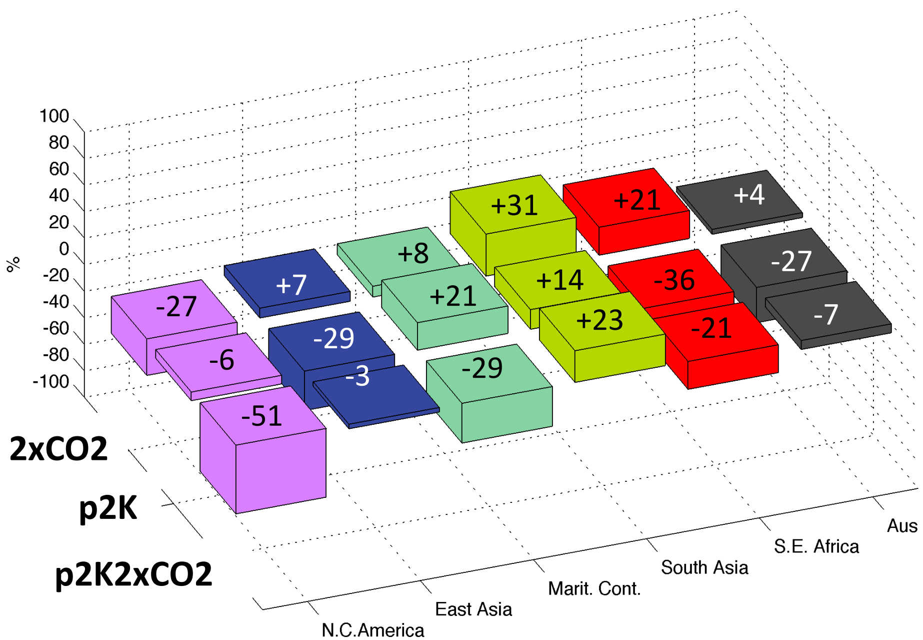


RESULTS

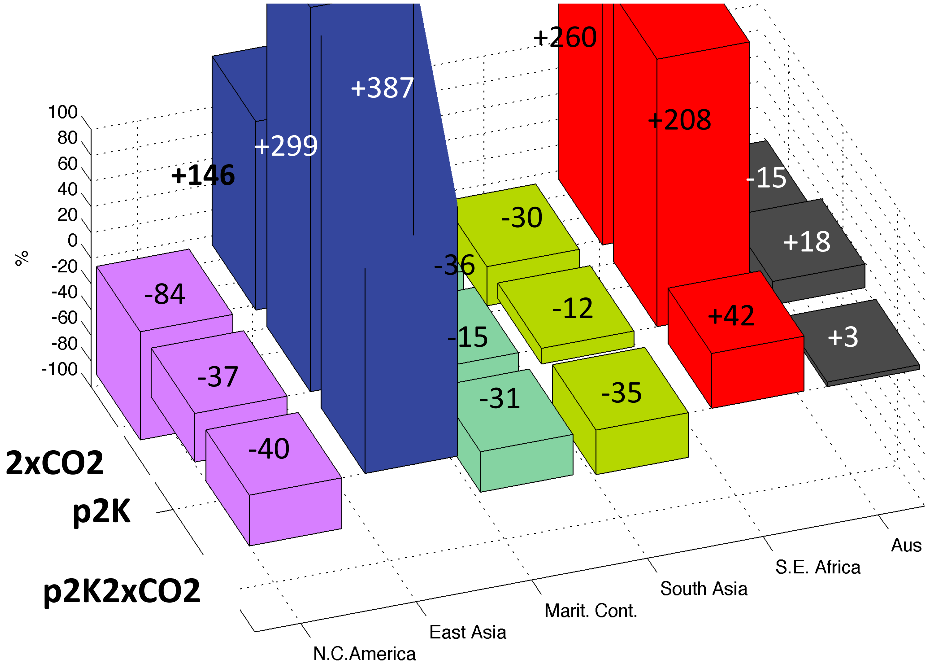
Changes in the total amout of water associated to TCs OVER LAND in the HWG experiments



GFDL TC precipitation increase [% wrt CONTROL]

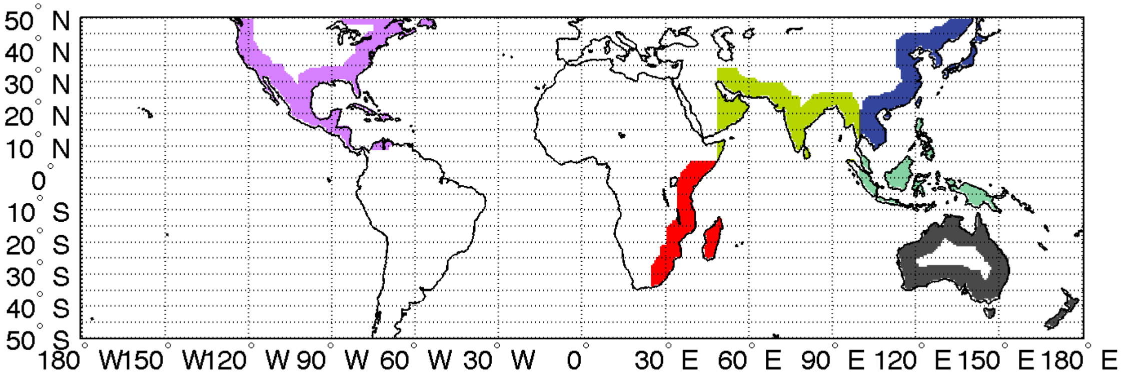


CMCC TC precipitation increase [% wrt CONTROL]

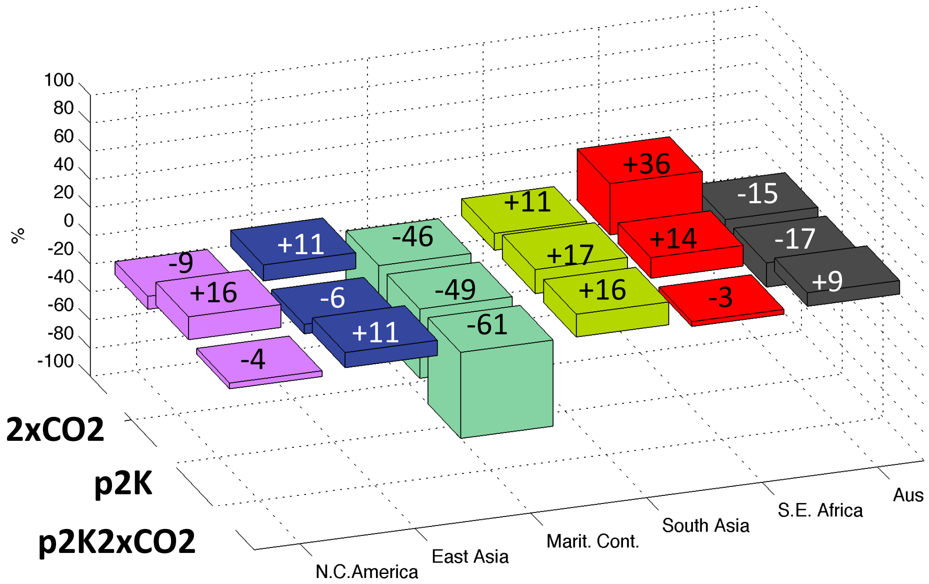


RESULTS

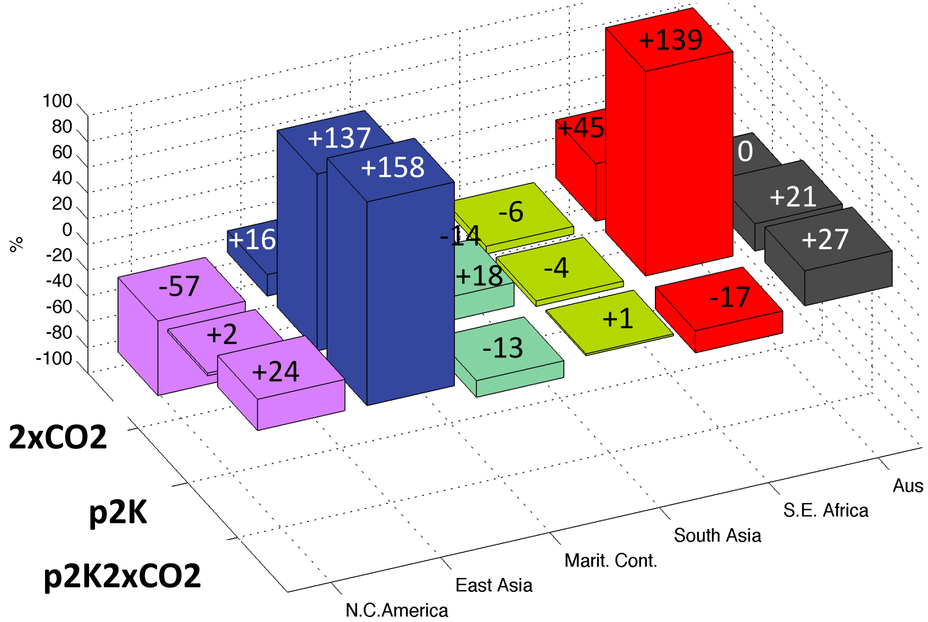
Changes in the total amout of water associated to TCs OVER LAND, NORMALIZED BY TCs DAYS



GFDL TCprecip/TCdays increase [% wrt CONTROL]



CMCC TCprecip/TCdays increase [% wrt CONTROL]



CONCLUSIONS

1. Global patterns of **precipitation associated with TC activity** are reasonably well **represented by the considered GCMs**. GFDL model (50 Km) performs better than CMCC model (80Km).

2. In terms of **amount of water associated to TCs at global scale**, in 2xCO2, p2K and p2K2xCO2 experiments, the **CMCC model shows more pronounced changes wrt GFDL model** (**resolution**?, different **precipitation parameterization**?).

3. Changes in the amount of **water associated to LANDFALLING TCs are more pronounced if compared to changes in the corresponding basin**. The obtained results are not coherent between models.

NEXT STEP:

- Improve the statistics: - period 10y ->20y
  - include all available HWG GCMs precipitation (daily) res.

- Verify the relationship between precipitation results and the general circulation associated to each model/experiment (CAPE, low level vort., winds, etc.).

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thank you!

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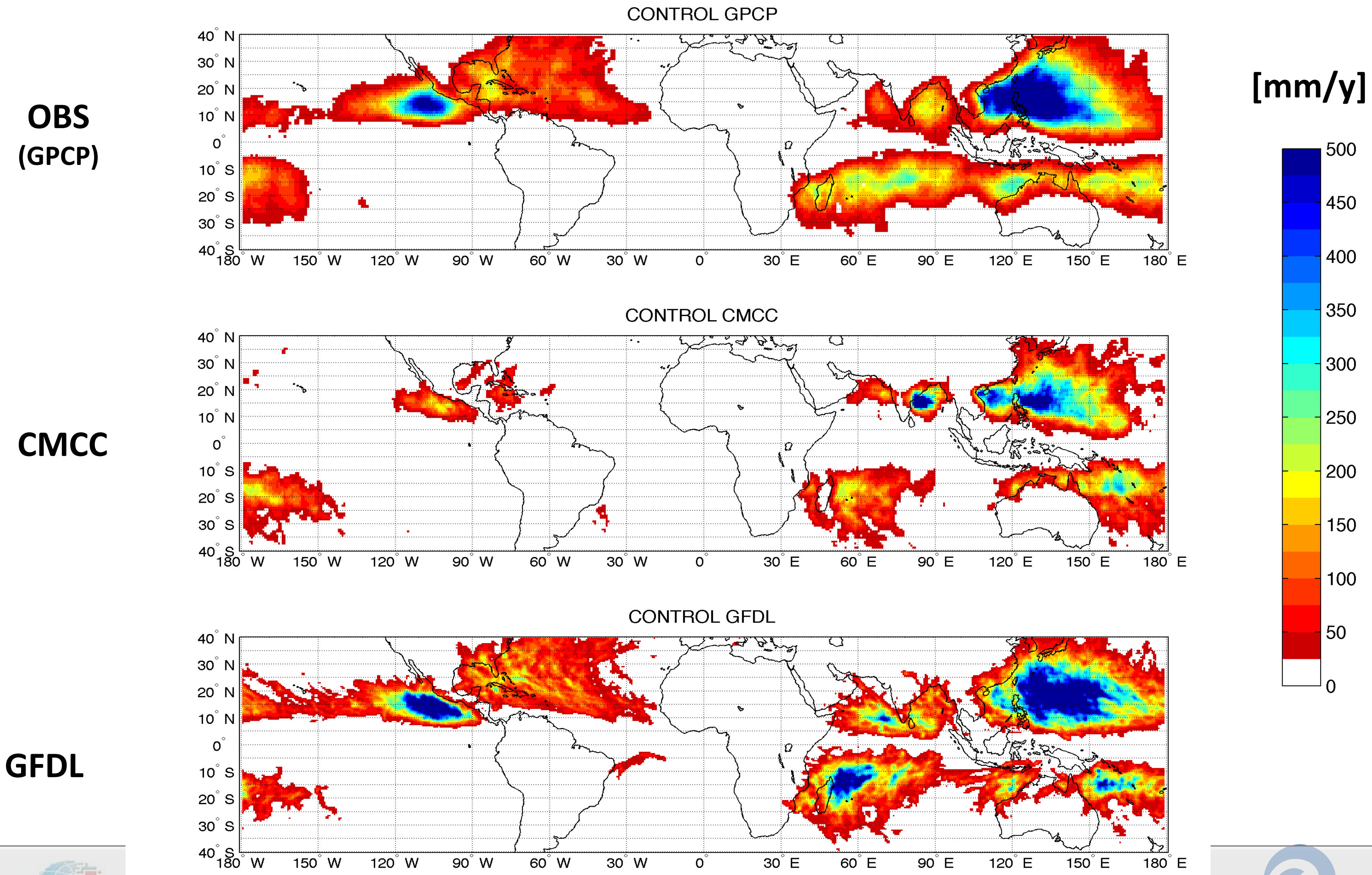
RESULTS

Precipitation associated with TCs in the CONTROL (10y) experiment [mm/y]

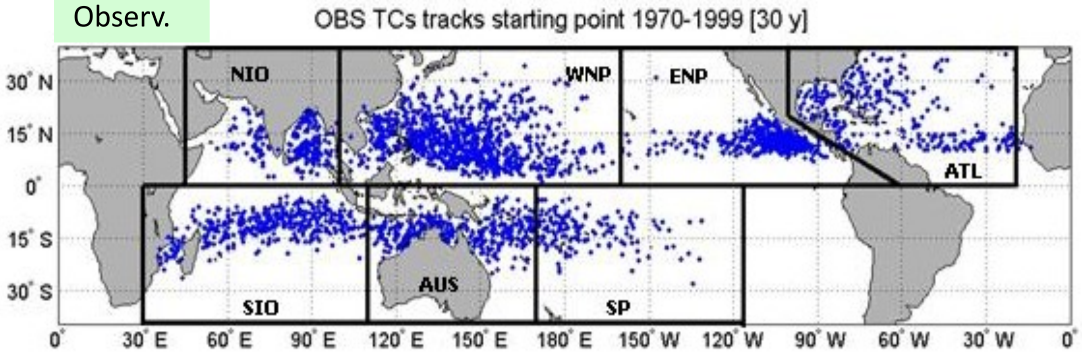


Tropical Cyclones as simulated by CMCC-INGV fully coupled climate models

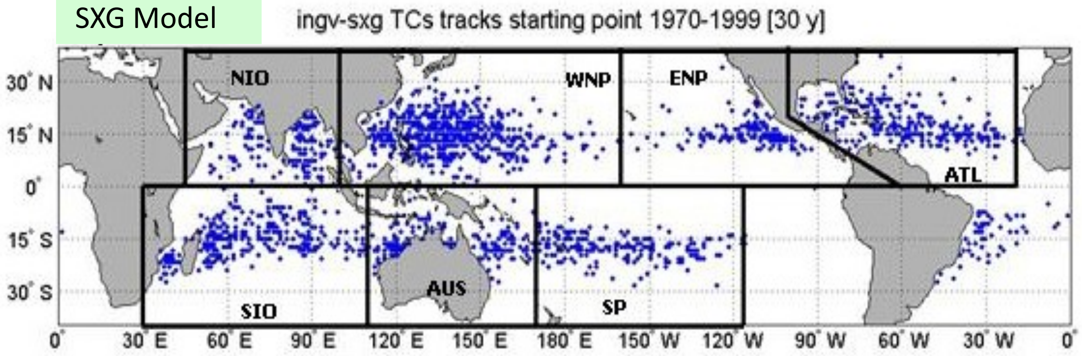
COUPLED MODELS at CMCC

Tropical Cyclone tracks starting points 1970-1999

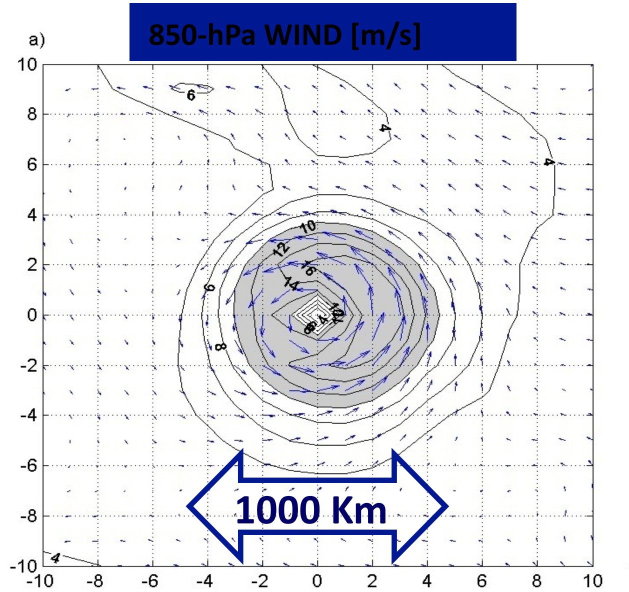
Observ.



SXG Model



Composite of a simulated TC



Annual TC number in a warmer climate

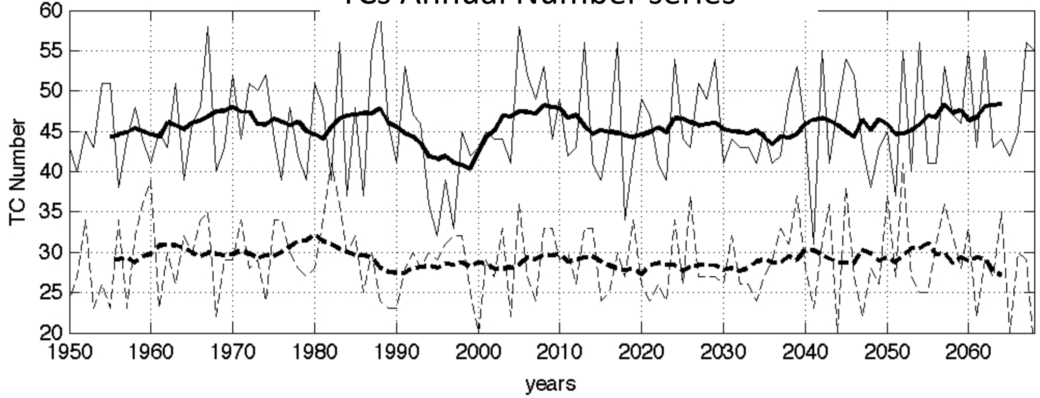
	Preind	2xCO2	4xCO2
WNP	27	20	14
ATL	9	7	4

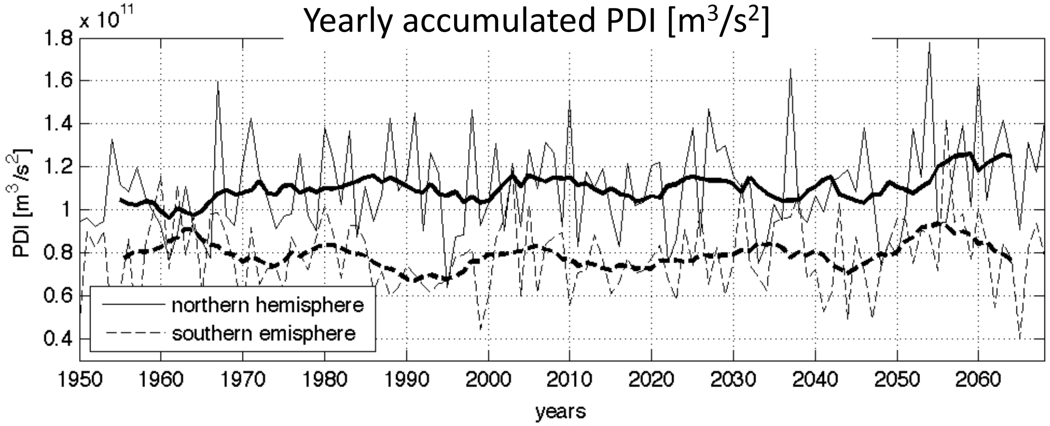
Changes in Tropical Cyclone Activity due to Global Warming: Results from a High-Resolution CGCM
Gualdi et al. 2008 - *J. of Climate*, Vol. 21, pp. 5204-5228

Tropical Cyclones as simulated by CMCC-INGV fully coupled climate models:
INGV-SXG (atm: echam4, T106) and CMCC_MED (atm: echam5, T159)

COUPLED MODELS at CMCC

CMCC-CM TCs annual number and Power Dissipation Index (PDI)

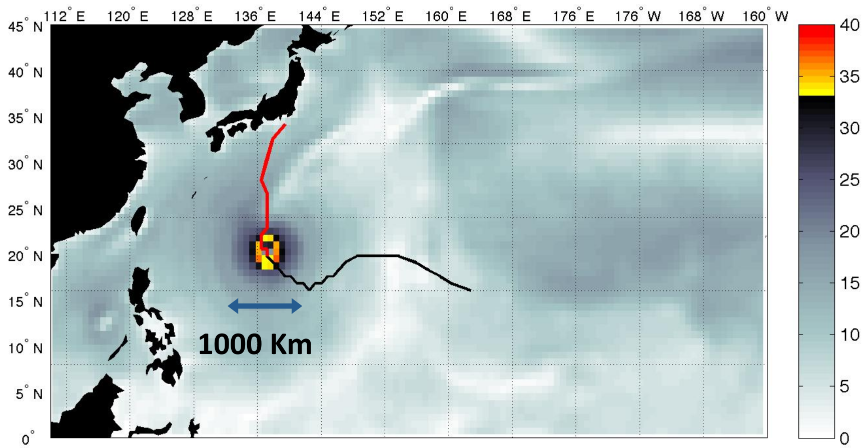




Annual TCs number and variability

	OBS	INGV-SXG (T106)	CMCC-CM (T159)
TCs/y	93.8	66.2	80.2
STD	10.9	9.2	7.5

Hurricane detection in CMCC-CM: 10m wind speed > 33 m/s



-**Changes in Tropical Cyclone Activity due to Global Warming: Results from a High-Resolution CGCM.**
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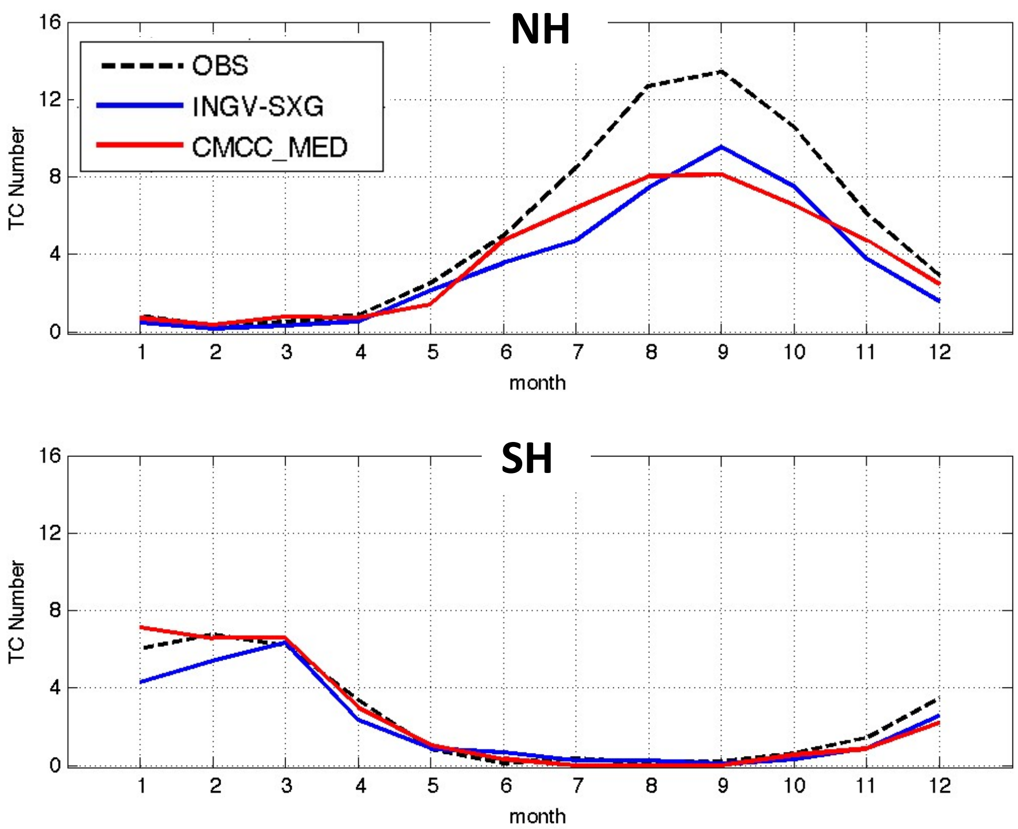
-**Effects of Tropical Cyclones on Ocean Heat Transport in a High Resolution CGCM.**
Scoccimarro et al. 2011 - *J. of Climate, in press*. Doi: 10.1175/2011JCLI4104.1

Tropical Cyclones as simulated by CMCC-INGV fully coupled climate models: INGV-SXG (T106) and CMCC-CM (T159)

COUPLED MODELS at CMCC

Seasonal Modulation of TC activity



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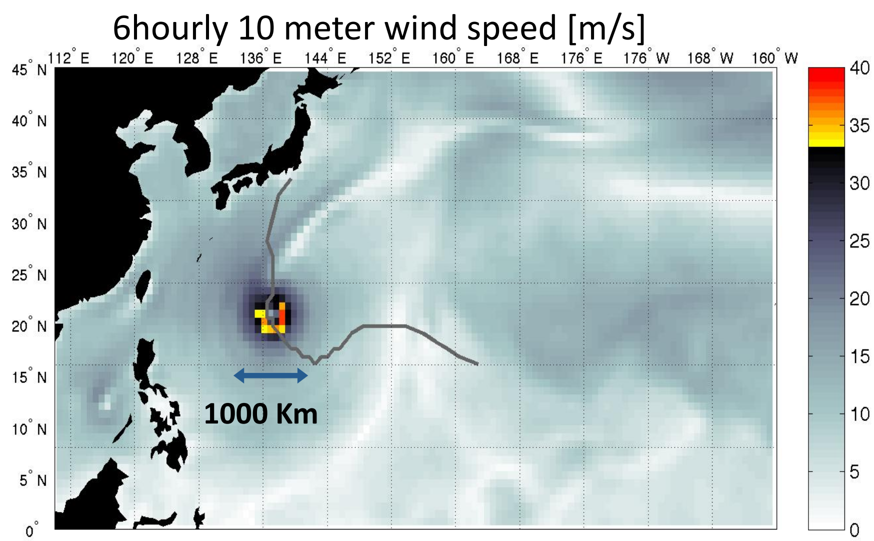

Now moving from MPI ECHAM based atmospheric model to NCR/UCAR-Community Earth System Model (CESM):
CMCC developed the coupling with the Nucleus for European Modelling of the Ocean (NEMO) GCM.

COUPLED MODELS at CMCC